EXPERIMENTAL BIVALVE TAPHONOMY IN REEFS OF MADANG LAGOON, PAPUA NEW GUINEA

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INTRODUCTION

Tropical skeletonized marine taxa compose an important taxonomic diversity concentration (Brown and Lomolino 1998) and they play a substantial role in carbonate burial within the global carbon cycle (Opdyke and Walker 1992; Milliman 1993). However, despite their importance, we know little about processes controlling the post-mortem fates of skeletal carbonate, that is their taphonomy. This means that we have little insight into potential bias in the record of past biodiversity, and only broad estimates of their importance in carbonate recycling.

Most taphonomic studies have been conducted in temperate latitudes, including experimental work (Peterson 1976). Some laboratory studies have examined the effect of temperature (Kidwell and Baumiller 1990), and mineralogy (Walter 1985), aspects that vary between temperate and tropical settings. In the early 1990's, tropical studies were limited to coral bioerosion (Hutchings 1986; Kiene and Hutchings 1994), and there was a lack of information on rates of overall skeletal degradation in tropical reef environments, sites of such high biodiversity and biogenic activity. A few studies published through the 1990's have since provided some additional perspective (e.g. Parsons 1993 - bivalve death assemblage, Lescinsky et al. 2002 - bivalve experiments, Pandolfi and Greenstein 1997 - corals, Greenstein 1991 - echinoids).

This study examines the experimental response of bivalve shells deployed in reef environments of Madang Lagoon, Papua New Guinea, over the period of one year (1992-1993), and was designed with a parallel experiment on corals (see Estrada-Alvarez et al. 2004, this volume). Experimental arrays can be a powerful means of determining relatively short-term rates and pathways of skeletal degradation under specific conditions in natural environments. The experimental design consists of 3 sites: a low energy, higher nutrient fringing reef at Nagada Harbour, a moderate energy back lagoon fringing reef at Gosem Island, and a high energy mid-lagoon patch reef at Paddoz. At each site articulated specimens of 2 bivalves species (*Gafrarium tumidum* - low organic microstructure, and *Geloina coaxans* high organic microstructure and periostracum) were deployed both at and ~10cm below the sediment/water interface. Each design was replicated 4 times, for a total of 48 articulated shells (96 valves). Observations were made at 1.5 months and 12 months after deployment. All shells were present at 1.5 months, 79% of the shells were recovered after 1 year, with all losses at the high energy Paddoz site. Shells deployed at the sediment/water interface were expected to be more affected by biological and physical processes such as encrustation, bioerosion, fragmentation, and abrasion. Those buried should have been more affected by chemical processes, such as precipitation and dissolution due to the early diagenetic evolution of sediment porewaters.

RESULTS AND DISCUSSION

<u>Ligament and Disarticulation</u> - Ligament remained on most *Geloina coaxans* shells for at least one year, whereas it was largely absent on *Gafrarium tumidum*. Consequently, only 5% of the *Gafrarium tumidum* shells were still articulated compared to 33% for *Geloina coaxans*. Paddoz is the only site that showed disarticulation at 1.5 months, and then a higher rate for exposed vs. buried shells, suggesting the high energy at this site played a role (Figure 1). A difference is also observed between buried and non-buried shells at Nagada, where the articulation of buried shells is higher than those exposed at the sediment-water interface. These results suggest that size and rate of decay of the ligament controls disarticulation, that disarticulation may be further slowed by burial in low energy environments, and that in high energy environments increased physical and/or biogenic activity accelerates disarticulation.

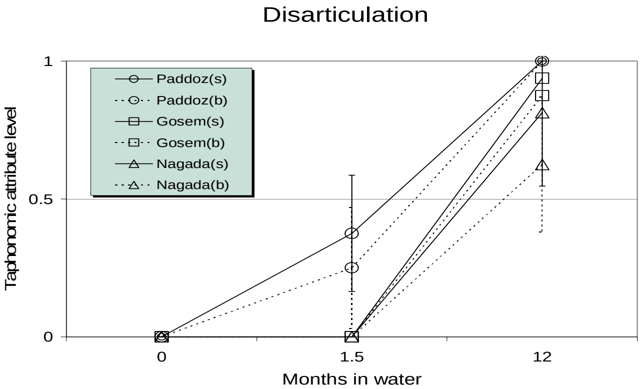

Figure 1: Average disarticulation of shells among sites and between depths, plotted through time. Y-axis: 0=articulated, 1=disarticulated whole valves

<u>Periostracum</u> - *Geloina coaxans* is the only experimental species having periostracum. After one year, almost all shells have partially or completely lost their periostracum among the three sites. However, periostracum remaining increased from Paddoz to Nagada and only shells from Nagada have complete periostracum. Also, periostracum seems to be less susceptible to degradation under the sediment surface.

<u>Surface Alteration</u> – The degree of surface alteration (a function of dissolution, abrasion, and miocroboring) varies among the sites, and between surface and buried shells (Figure 2). The surface of exposed shells at Nagada and Gosem is almost always obscured by encrustors, whereas at Paddoz sections of the exposed shells show alteration, probably due to abrasion. Buried shell surfaces at Nagada show the least amount of modification (pristine/dull, a little chalkiness probably due to dissolution), whereas at Gosem they show significant degradation (chalky and pitted), probably due to microboring. Both buried and exposed shells at Paddoz show similar surface alteration, as most buried shells in fact show signs of exhumation.

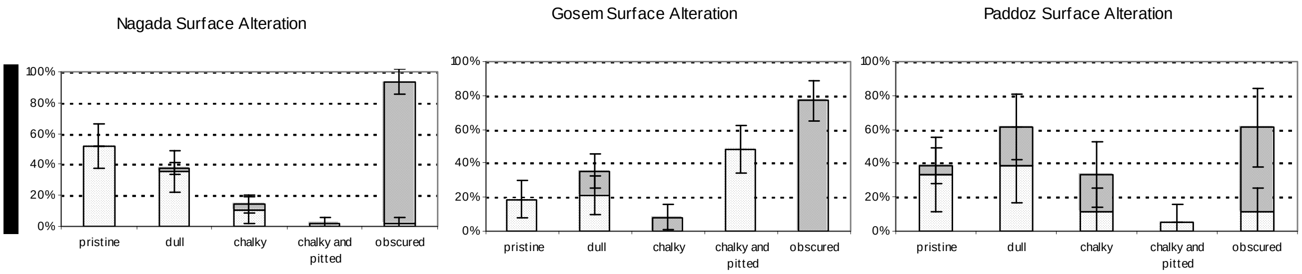

Figure 2. Surface alteration of shell interiors among the sites and between depths. Exposed shells indicated by striped bars, buried shells by dots.

Encrustation

At 1.5 months the first encrustors to appear on shells among the three sites were calcareous algae, spirorbid/serpulid worms, and fleshy algae. After one year, the taxa of encrustors differed slightly between the three sites (Figure 3). At Paddoz, calcareous algae, bryozoa, and spirorbid/serpulid worms were most common, only disc forams were missing. At Gosem, spirorbid/serpulid worms, calcareous algae, and disc forams were very abundant, bryozoans and *Homotrema* were absent. At Nagada, the taxa are less abundant than both Paddoz and Gosem, with the exception of a relatively high frequency of *Homotrema* (Figure 3). In terms of surface coverage, bryozoans are more extensive in Nagada and very low in Paddoz.

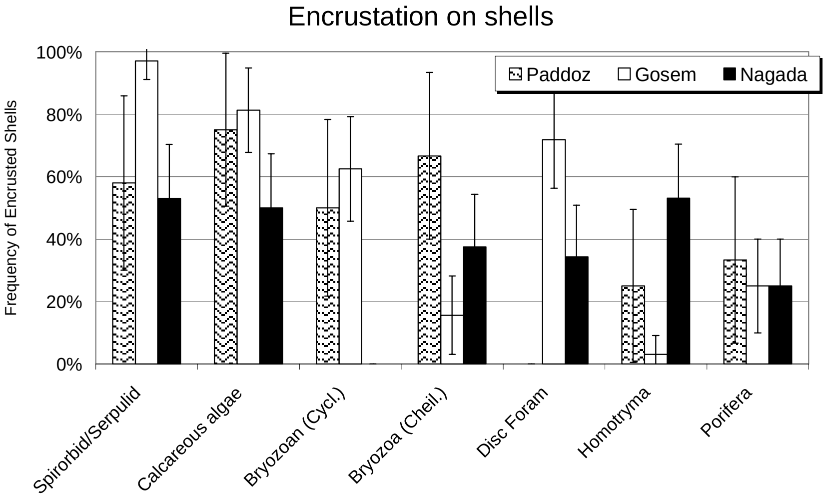

Figure 3: Frequencies of shell encrustation are shown for 7 different encrustors from the three different sites.

Among the three sites shells on the surface have been much more encrusted than those buried, but the difference is significantly higher at Nagada. Shells on surface of sediments were encrusted very rapidly at both Gosem and Nagada. In general, *Geloina coaxans* was slightly more encrusted than *Gafrarium tumidum*, perhaps because of the larger surface area of the shell.

Boring – No macroscopic signs of boring were found after 1.5 months, however after one year 50% of the shells show signs of boring. Based on morphological characteristics, three different traces were identified. The most common boring types overall are worms and *Cliona*, however microboring is also common at Nagada, perhaps due to increased nutrients at this site (Figure 4). Between the experimental species, *Geloina coaxans* was three times more likely to be infested by borers than *Gafrarium tumidum*, suggesting that the higher organic microstructure of *Geloina* makes it more susceptible to infestation. Buried shells were least affected by boring, with the exception of worms that were more abundant in buried shells than in sediment surface shells.

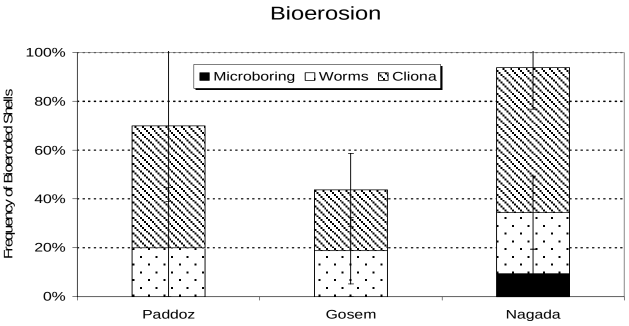

Figure 4: Frequency of bored shells and the types of infestation among the three sites.

Biological interactions

Overlapping relationships show that spirorbid/serpulid worms have colonized the shells before or during the same time as calcareous algae. After 1.5 months, calcareous algae covered more surfaces and overlapping of spirorbid/serpulid worms by calcareous algae is the commonest interaction at Gozem and Nagada. After one year, calcareous algae and spirorbid/serpulid worms were still the major encrustors in the three sites. Since calcareous algae had covered more and more surface, spirorbid/serpulid worms overlapping calcareous algae were then observed. At Gosem and Nagada, disc forams seem to have colonized the shells after calcareous algae as numerous disc forams overlap calcareous algae. Some interactions also occurred between later sponges and earlier calcareous algae. Finally, boring occurred in the late stage of the experiment: it was not observed after 1.5 months and after one year was often observed to occur after encrustors.

Degradation processes were very sensitive to exposure at the sediment/water interface. Less contrast between buried and exposed shells in Paddoz and Gosem compared to Nagada is likely due to episodic exhumation of the buried shells by bioturbation and/or storms. Encrustation on some buried shells is explained by these periods of exhumation.

SUMMARY

(1) Experimental buried shells were better preserved: Rates of encrustation and boring were higher for exposed shells than buried, ligament and periostracum were more likely to persist during burial.
(2) Similar reef energy levels between Gosem and Nagada resulted in similar patterns. However, they are significantly distinct from Paddoz based on lower shell loss, disarticulation, and loss of periostracum, and higher encrustation rates.
(3) *Geloina coaxans* had higher rates of taphonomic modification than *Gafrarium tumidum*, as it had a higher rate of disarticulation, bioerosion, and encrustation.
(4) The major encrusters on experimental shells were calcareous algae, spirorbid/serpulid worms and disc forams. The boring activity of worms and *Cliona* played an important role in the degradation process.
Exposure is the most important factor increasing shell modification in this study. High water energy causes shells to go through burial exhumation cycles. Under exposure conditions, biogenic modification outweighs physical effects, even at the high energy site. Extensive effects are noted within a year, indicating the extent to which these are harsh taphonomic environments where significant skeletal loss is likely.

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SKELETAL CARBONATE PRESERVATION IN THE ARCTIC: EXPERIMENTAL AND DEATH ASSEMBLAGE PRELIMINARY RESULTS FROM ICE SCOUR ENVIRONMENTS.

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Scouring by sea ice is a significant physical agent of sediment reworking on the Arctic Shelf. If present in considerable amounts, skeletal death assemblages can be used as tracers for these time-averaging processes in addition to giving insight on sources of bias that might affect the fossil record in these environments. Death assemblage was collected from in ice scour environments of Resolute Bay, NWT, Canada, during August 1996. Most of the scours are within 30m water depth, recorded in the glacial clay sediment. Preliminary results indicate that all sites contain shell material. 56% of the sites outside, inside and at the berm of the ice scour have shell material as greater than 50% of the total coarse fraction (>2mm). These values show that calcium carbonate hard parts are present in the Arctic and get preserved in siliciclastic sediments.

Fragmentation level was evaluated in a 2 year old scour and shows a slight increase in fragmentation going from the outside of the scour towards the inside. Whole valves were 3% of the total bivalve assemblages outside the scour, compared to 1.7% at the berm and 0.6% inside the scour. 90.1% of the shells are highly fragmented outside the scour, with 90.7% of the shells at the berm and 97.1% inside the scour. These values are all extremely high when we compare with other marine environments where maximum fragmentation values range around 75%.

Parallel to the death assemblage analyses, we are evaluating the preservation of experimental *Mytilus edulis* shells deployed in Franklin Bay, Beaufort Sea, for 4 weeks in April 2004. The experimental shells were subject to three different environments: water column, sediment-water interface and buried in the sediments. The maximum weight loss is 1.2%, 1.2% and 1% respectively. On average, shells in